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CLIFT ISLANDS IN THE CORAL SEAS

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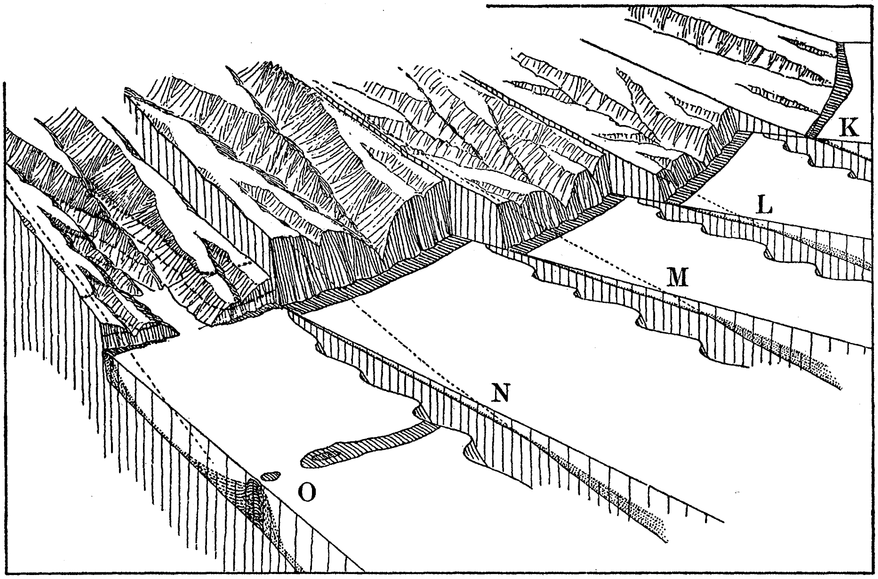
The great majority of reef-encircled islands in the Coral Seas are of maturely dissected form, with slopes of moderate declivity that descend to an indented shoreline, where the tapering spurs end in salient points and the widening valleys open into branching bays, thus proclaiming that the islands have suffered partial submergence since they were dissected. It is generally agreed by those who accept this interpretation of insular relief in relation to shoreline pattern that the encircling barrier reefs have grown upwards from their beginning as fringing reefs during the subsidence which gave the shoreline its indented outline. Reasons for this conclusion were given in a previous article 'The Origin of Coral Reefs' in these PROCEEDINGS **1**, 146–152, 1915; they have been more fully stated in 'A Shaler Memorial Study of Coral Reefs' recently published in the *American Journal of Science*, **40,** 223–271, 1915.

The object of the present article is to call attention to certain exceptional reef-encircled islands, Reunion, Tahiti, and New Caledonia, in the Coral Seas, which present clift shore lines, and to suggest an explanation by which their exceptional features may be simply accounted for. If all the islands of the Coral Seas were clift like these three, they would support either the theory of veneering barrier reefs on wave-cut platforms, or the Glacial-control theory of coral reefs. But clift islands are exceptional. Some means of explaining them must be found which will not be in discord with the theory of coral reefs that is supported by the features of non-clift islands, namely, Darwin's theory of intermittent subsidence. It will appear from what follows that the suggested means of explaining the exceptional clift islands of the Coral Seas gives unexpected support to this theory.

Imagine a young volcanic island, from which detritus is washed so abundantly into the sea that corals and the associated reef-making organisms can establish themselves if at all, only in short and discontinuous fringing-reef patches around its shore. So long as the island continues to grow by eruption, its height and perimeter will increase; its earlier fringing reef patches will be buried under newer lava flows, agglomerate beds and ash falls. The completed volcanic island will have a shoreline of simple pattern without pronounced salients and reentrants, because the materials ejected from the summit crater are spread rather equably on all sides of the cone, and thus give it a nearly circular base. The simple shoreline may be at first somewhat prograded by the deltas of the larger streams, sector K of the figure; between the deltas it may be somewhat retrograded and clift by the waves; but an abundant supply of cobbles, gravels and sands from the delta fronts will be swept along the inter-delta shores in the form of beaches that will cover the cliff-base platforms; and the finer sediments will be spread seaward on the submarine flanks of the volcanic mass. The deltas, the beaches and the off-shore sediments will form a detrital sheet, thickest and of coarsest texture on the deltas, of finest texture and for a time thinnest where it slopes into deep water; but as time passes, the fine-textured, off-shore sediments will come to exceed all other parts of the detrital sheet in thickness, for when retrogradation begins and the deltas are cut back in the general retreat of the shoreline, sectors L, M, N, the stream-mouth deposits will be hardly thicker than the cliff-base beaches. Small patches of fringing reef may at first form on the bare unreduced ledges that here and there protrude through the cliff-base beaches; but elsewhere the materials of the detrital sheet are too commonly in movement to permit coral growth.



After volcanic eruptions have definitively ceased and the normal dissection of the cone by weather and streams and the cutting of cliffs around the simple shore by waves are further advanced, it is probable that the first formed reef patches will be overwhelmed by the increasing continuity of the detrital sheet, and if this unfavorable condition for reef development once sets in, it is likely to continue indefinitely, as long as the island stands still. The grinding of the detritus upon itself, as it is shifted by the waves, would soon reduce it to so fine a texture that it would all be swept off the platform into deep water, leaving the platform bare; but the loss thus occasioned is continually made good by a new supply from the valleys and cliffs of the island; hence the detrital sheet is always maintained. The rasping of the detritus on the platform, especially at the time of storms, slowly wears the rock surface down to greater and greater depth, but the degradation thus caused is probably 20 or 40 or more times slower than the retrogradation of the cliffs. The 'edge' at the outer margin of the abraded platform may be somewhat accentuated and stript as it is worn down, because the slow abrasion of its rock surface may be exceeded by the more rapid abrasion of the first deposited detritus next outside of it: here corals and other reef building organisms might grow, but for the constant outward passage of detritus which would smother them. The important matters to note thus far are first, that when the series of normal changes begins around the simple shoreline of the completed island, sector K, the shore waves will at once have to deal with so abundant a supply of detritus washed down by torrents, that a continuous shoreline beach and off-shore detrital sheet will be formed at an earlier stage of shoreline development than is usually the case on the shores of strongly sloping coasts; second, that the detrital sheet, once established, will be thereafter well supplied with waste from the deepening valleys and the retreating cliffs, and will thus be maintained indefinitely, as long as the island stands still; and third, that as long as the detrital sheet exists, the growth of corals is greatly discouraged if not entirely prevented.

Now let it be supposed that when a certain stage of cliff recession is reached, as in sector N, the island subsides by a succession of starts and stops, so that the shoreline crosses the cliffs at mid-height and enters the larger valleys, as in sector O. Several significant changes will follow. The detritus from the larger valleys of the dissected cone will now be pocketed in the valley-mouth embayments; the waves, beating the face of the cliffs without the aid of the boulders and cobbles, with which they had previous attacked the cliff base so successfully, will do little work in the way of cutting the upper half of the cliffs farther back. Under these conditions corals and their associates may attach themselves to the cliff face and form a fringing reef; as soon as such a reef broadens a little, it will hold nearly all the detritus that is washed from the little hanging valleys and weathered from the non-submerged part of the cliff face: thus the detrital sheet on the abraded platform, no longer receiving a renewal of supply from the cliffs or the streams, will be slowly shifted seaward and the rock platform will be at least in part exposed, especially along the 'edge' at its outer margin, where the heavy outside storm waves make their first attack on the bottom: here in particular, the abraded rock of the platform may be laid bare and a favorable site for coral colonies provided; here, if the subsidence has not been too great, a barrier reef may grow up, as in the side section of Sector O.

As soon as the barrier reef is fairly well established, wave work in the lagoon is greatly weakened. If the island now stand still again, the lagoon will be gradually aggraded by overwashed detritus from the reef, by organic deposits formed in the lagoon, and by outwashed detritus from the island: thus a delta-and-reef plain will in time replace the lagoon, and when this stage is approached and reached, the stream-borne volcanic detritus will be again delivered on the reef face, where it will retard the growth of corals and their associates. But if subsidence be renewed and the shore line rise to the broken line of sector O favorable conditions will be re-introduced, and the barrier reef will grow upward again. The cliffs that were cut before subsidence began will in time be completely submerged; the shoreline will then have the pattern shown by a dotted line in sector O, and this pattern will persist as long as subsidence continues, until in the almost-atoll stage the diminishing island is reduced to so small a size that it has no room for valleys; only a central summit will then remain above sea level; in the next stage this disappears, and a perfect atoll results.

Actual examples of islands and reefs should be found in various stages of the sequence of events here deduced, if the scheme by which the deductions are guided is a true counterpart of natural occurrences. Reunion in the western Indian Ocean offers confirmation for sectors K and L. As described, figured and mapped by Maillard, and especially by von Drasche, it has no embayments; part of the shoreline is clift with hanging valley mouths; much of the shoreline is delta-fronted and beached; and coral reefs form only fragmentary fringes along about one-tenth of its circuit.

Tahiti, a volcanic doublet in the Society group of the South Pacific, is clift nearly all around its figure-8 circuit. The cliffs, well described by Agassiz, are highest on the eastern or windward side where some of them rise 1000 feet above the sea; a number of the smaller valleys make mere notches in the cliff top, and the streams cascade down the cliff face; a few of the larger valley mouths are still embayed as all of them once were; hence the island has subsided and the cliff base is submerged Most of the embayments are now filled with deltas, which are indeed advancing into the lagoon, where they form a narrow alluvial plain on which most of the population dwells. A barrier reef rises at just about such a distance off shore as to suggest that its foundation is on the edge of the abraded platform that fronts the submerged base of the cliffs; volcanic detritus is abundant in the enclosed lagoon. Tahiti thus seems to have been clift, about as in sectors L, M or N, and then to have subsided as in sector O; since then it has stood still long enough for abundant delta advance and for partial enclosure by a barrier reef, the further growth of which is now threatened at certain points by the advancing deltas.

New Caledonia is peculiar in being a non-volcanic island, and in being clift only on the northeastern side: hence certain special assumptions must be made in order to bring it under the explanatory scheme here proposed; but the necessary assumptions do not involve any events that are not made probable by what is known of the geological and physiographical history of the island.

The great majority of reef-encircled volcanic islands in the Pacific are volcanic, like Reunion and Tahiti; but they differ from these two submaturely dissected cones in being maturely or more than maturely dissected, so that hardly a trace of their initial conical slopes remains; furthermore, their spurs usually taper to non-clift points and their valleys open into broadening bays, as shown in the dotted high-level shoreline of sector O. If the reef-encircled islands of the Pacific have formerly passed through an introductory, almost reefless stage, like Reunion, and a soon-following reef-encircled stage with partly drowned cliffs and outgrowing deltas, like Tahiti, they have since then continued their subsidence as well as their dissection and their reef growth, so that at present they have no trace of the smooth slopes of their initial conical form, and no trace of the presumable spur-end cliffs of their early reefless stage: they have gained forms that are best explained on the supposition that, whether they past through an introductory reefless stage or not, they have long suffered dissection and intermittent subsidence, while protected from wave attack by an upgrowing, encircling barrier reef.

A theory of coral reefs is certainly commended when a reasonable extension of its postulated conditions and processes enables it to account for the cliffs of exceptional reef-encircled islands, for which no adequate explanation has been previously given.